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HF BROADBAND WHIP ANTENNA

EVALUATION

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Present Navy shipboard antenna couplers used with whip antennas will not suffice for future frequency agile transmitting systems. A new broadband whip antenna which operates without a coupler should be evaluated for potential application in a frequency hopping mode. VSWR for various mounting configurations and gain relative to a 35 foot whip were measured in this initial portion of the evaluation. VSWR was typically less than 2:1 and relative gain averaged -19 dB with respect to a standard Navy 35 foot whip.

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INTRODUCTION

Marine whip antennas typically operate as monopoles, and when mounted on ships, exhibit input impedance characteristics over the HF band (2-32 MHz) which vary greatly from the classical 50 ohm load impedance to which most transmitters and receivers are designed. Most U.S. Navy whips are 35 feet long and are quarter-wave resonant at approximately 7 MHz. Below 7, the whip is capacitive and the radiation resistance drops to a value of 2 ohms at the lower limit of 2 MHz. Above 7 and up to 14 MHz, typical input impedance swishes around the Smith Chart with VSWR values ranging from 1.3:1 to 22:1. At 14 MHz, half-wave resonance produces a high resistance and high VSWR. Every 7 MHz thereafter will show additional low and high impedance resonances with inductive and capacitive reactances in between.

The usual method for taming the wild impedance excursions and allowing reasonably efficient power transfer to communication tranceivers wanting 50 ohm antennas is to use impedance transforming and reactive matching units called antenna couplers. Modern Navy whip couplers are quite efficient with less than 1 dB of insertion loss above 2 MHz and worst case loss or -3 dB down at 2 MHz. Many of today's couplers are auto-tune units, meaning they automatically sense reflected power and adjust their internal variable inductors and capacitors for minimum VSWR. This process can take as long as 45-60 seconds and is seldom complete in less than 2 seconds.

Future Navy frequency-hopping communication systems may jump between widely different frequencies at a rate that exceeds one thousand steps per second. The present state of coupler technology eliminates standard whip-coupler antennas for application with these frequency-hop systems. What is needed is a broadband radiator with VSWR less than some reasonable value, 3:1 typically. Present Navy antenna designs which can achieve this type of

SUMMARY

Present Navy shipboard antenna couplers used with whip antennas will not suffice for future frequency agile transmitting systems. A new broadband whip antenna which operates without a coupler should be evaluated for potential application in a frequency hopping mode. VSWR for various mounting configurations and gain relative to a 35 foot whip were measured in this initial portion of the evaluation. VSWR was typically less than 2:1 and relative gain averaged -19 dB with respect to a standard Navy 35 foot whip.

performance are limited to rather large multiple-wire fan arrays. Typically, two such fans would be required, operating from 2-7 and 7-22 MHz. For destroyer class vessels and larger, this solution to the broadband antenna requirement is probably acceptable but for small lightweight, high-speed vessels such as a patrol hydrofoil missile craft (PHM), the structure required to support a set of fan antennas is too tall and too heavy. Only a "lightning-fast" coupler-whip combination seems acceptable.

DESCRIPTION OF ANTENNA UNDER TEST

Triad Micro-system, Inc. of Santa Ana, CA recently acquired a broadband Marine HF whip antenna which was advertised as a "extremely wide-band totally-passive HF vertical antenna requiring no ATU (Antenna Tuning Unit or Coupler)." Performance indicated VSWR of less than 2:1 from 1.5 to 30 MHz with 500 watts of continuous power handling and 2000 watts P.E.P. The whip is 7 m. (23 ft.) long and weighs only 9 kg., withstands 160 km/h winds and "requires no ground plane." The manufacturer also described several interesting characteristics:

1. Dielectric loading for more efficiency. (Distributed capacitively loaded monopoles have more uniform current distributions, hence more radiation.)
2. Low-Q radiator with a resistance of 4 times the feed impedance in parallel with the antenna. (Base loading resistors will absorb reflected energy but also some forward energy.)
3. Performance is similar to a 7 m whip and ATU combination. (A resistively loaded antenna would be expected to exhibit lower gain due to losses.)

A visual inspection shows fiberglass whip construction and an 18 inch long finned heat at the base, which contains the swamping resistors and a 3 port transformer element.

SCOPE AND LIMITATIONS OF THE MEASUREMENTS

A measurement program was undertaken to provide performance comparisons to a standard 35 foot stainless steel whip antenna. At NPS, the 35 foot whip was mounted on the corner of a 10 foot by 20 foot ground plane, on the 7th deck of the Electrical Engineering Building, Spanagal Hall. A micro-processor controlled HF transceiver with an automatic tuning unit was connected through a directional wattmeter to the 35 foot whip and then to the broadband 7 m whip.

Forward and reverse power measurements provided VSWR for the broadband whip. A receiving station was established at a distance of 1.5 km from the NPS campus. An EMC-25 field strength meter was used in conjunction with a 45 degree, 20 foot high sloping vee wire antenna to measure the ground wave signal transmitted from both whips for a relative gain comparison. The received signal strength was adjusted for the forward transmitter power at each frequency so that the same reference values applied to both antennas.

Additional mounting configurations were tested for the broadband whip. Mast mounts of 10 feet and 20 feet were available and were used for additional VSWR runs. An extreme case of an unfavorable environment, laying the whip down flat on the ground plane, was tested to see how effective the base matching circuitry was at suppressing high VSWR.

A power handling test was conducted at a typical VSWR of 1.9:1. Initially 500 watts continuous (rated power) was tried, then 750 w. and 1000 w. were applied, in an attempt to exceed the capabilities of the antenna.

VSWR, RELATIVE GAIN AND POWER HANDLING TEST RESULTS

A collection of discrete frequencies were chosen in the range from 2-30 MHz. Steps were selected for logarithmic frequency spacing, consistent with negligible interference to established services. VSWR runs are plotted in Figures 1-5. Figure 1, for the 10x20 foot ground plane, shows an average VSWR of 1.91:1 with two perfect match points at 16.25 and 27.5 MHz. The 10 foot mast mounting resulted in similar results, shown in Figure 2, with the high and low regions of VSWR shifted in frequency from the ground plane case. Figure 3 demonstrates a more "natural" mounting condition: a 20 foot mast under the 23 foot whip, providing a resonating path for reflected currents, which should serve to improve performance. Except at 2 frequencies above 24 MHz, the performance was, as advertised, at less than 2:1 VSWR. The 16 and 27 MHz resonances of the 10x20 foot ground plane and the 10 foot mast mount were not as obvious. The average VSWR here was 1.68:1.

Figure 4 shows that the base impedance swamping circuitry is quite effective and keeps the VSWR below 2.2:1 over 75% of the frequencies tested. This hints at possible low radiation performance because forward power is obviously being consumed along with the reflected power. Figure 5 is a composite of the first 4 figures and reveals that reasonable VSWR exists for all cases of mounting from 2 through 22 MHz. The higher frequencies where the antenna cannot be considered as "short" produce VSWR values up to 4:1.

The relative gain of the broadband whip compared to the 35 foot whip is plotted in Figure 6. The average value is -19.7 dB and represents the ability of the broadband whip to radiate a ground wave signal with a mounting location (10x20 foot ground plane elevated above the surface of the earth) similar to that found on a ship. Note the peaks of +2.5 dB and +1.2 dB which occur near 16 and 28 MHz. These two frequencies were the "best matched" frequencies of

the VSWR runs of Figure 1. Figure 7 is Figure 1 flipped over so as to allow comparison of VSWR and relative radiation efficiency. By overlaying the two curves it is clear that low VSWR equates to higher gain and vice versa. Power dissipation tests at 500 watts where conducted with a thermometer afixed to the center region of the heat sink (the input coaxial connnector is at the top of the heat sink) in an ambient environment of approximately 22° C. The temperature rose to 62° C within 18 minutes and it stabilized there during the rest of the one hour test. At 750 watts delivered to the antenna, the temperature rose to 70° C and stabilized in 15 minutes. For 1000 watts, the temperature stopped rising in 13 minutes and reached 82° C. No apparent damage resulted from this twice rated power test. The hottest part of the heat sink was at the connector point and was well above 100° C. These tests might have caused some internal changes, but the measured VSWR remained fixed throughout the runs.

CONCLUSIONS AND RECOMMENDATIONS

The broadband 7 meter whip tested in 3 different mounting environments suggests that mounting on the top of a 7 meter mast enhances the impedance match and generally produces VSWR of less than 2:1. A mounting configuration similar to those a typical shipboard location would provide (10x20 foot ground screen elevated above the surface of the earth) produces VSWR under 3:1 over the HF band but with a definite loss in radiation efficiency as compared to a standard 35 foot (10 meter) Navy whip/coupler system. The nearly 20 dB average loss in radiation might be acceptable for some applications such as short haul groundwave operation in the frequency range of 3-8 MHz using typical transmit power levels. Other applications should be subjected to evaluation via a communications link test, preferably with frequency hopping and in comparison to some standard antenna(s).

An example of a reasonably inexpensive test would consist of a microprocess-controlled HF transceiver, controlled by a micro-computer and utilizing an error-checking modulation scheme (such as a packet modem would provide). Such an experiment could compare standard whips and fan-like antennas by operating slowly enough to permit matching the whips at each frequency. It would verify the relative gain reported in this study and could identify applications where this type of radiator could be used on small combatants. The low efficiency could be overcome by applying higher power linear amplifiers, if the received signal strength were adequate.

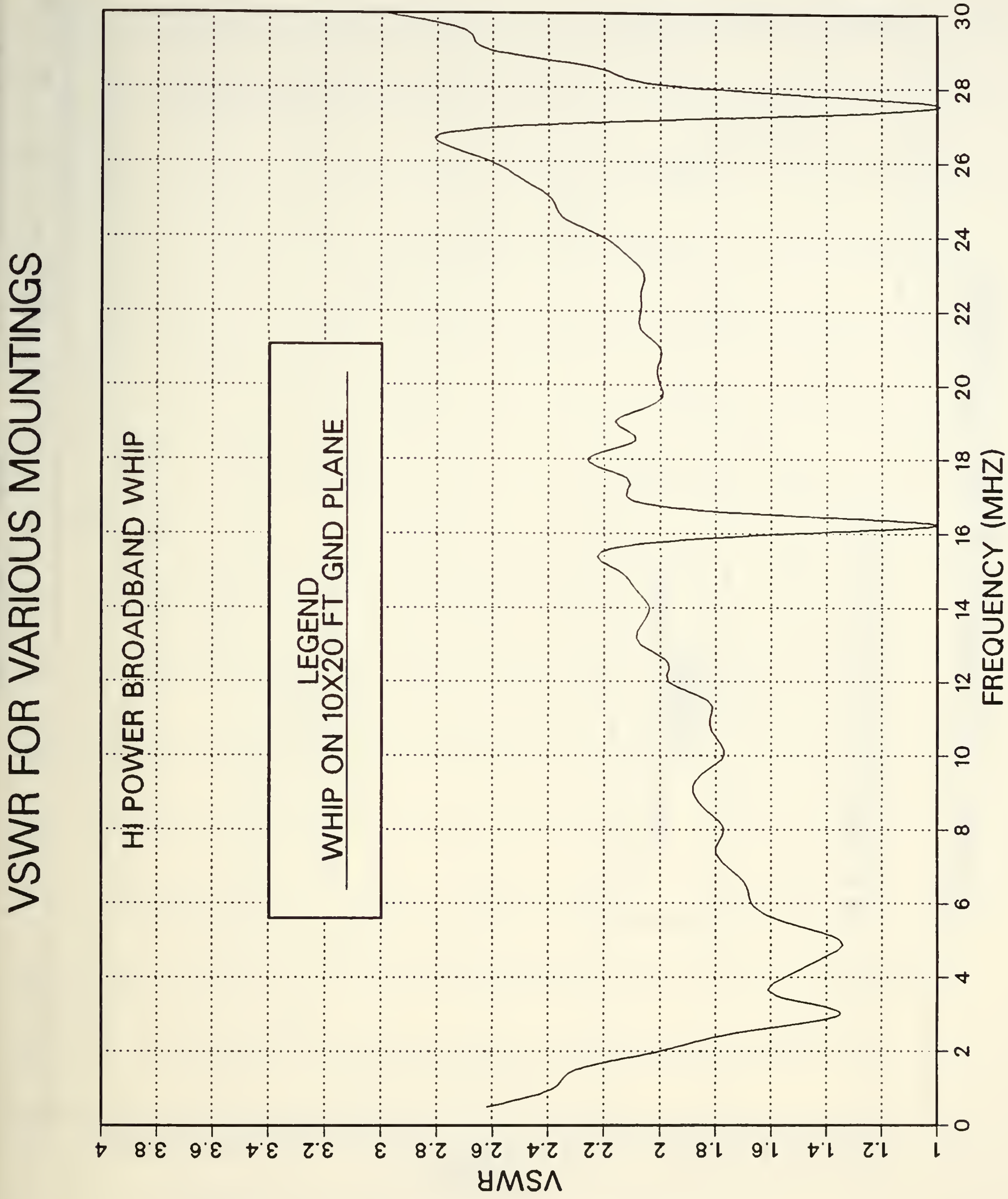

Fig. 1. VSWR vs. Frequency for 10 x 20 Foot Ground Plane

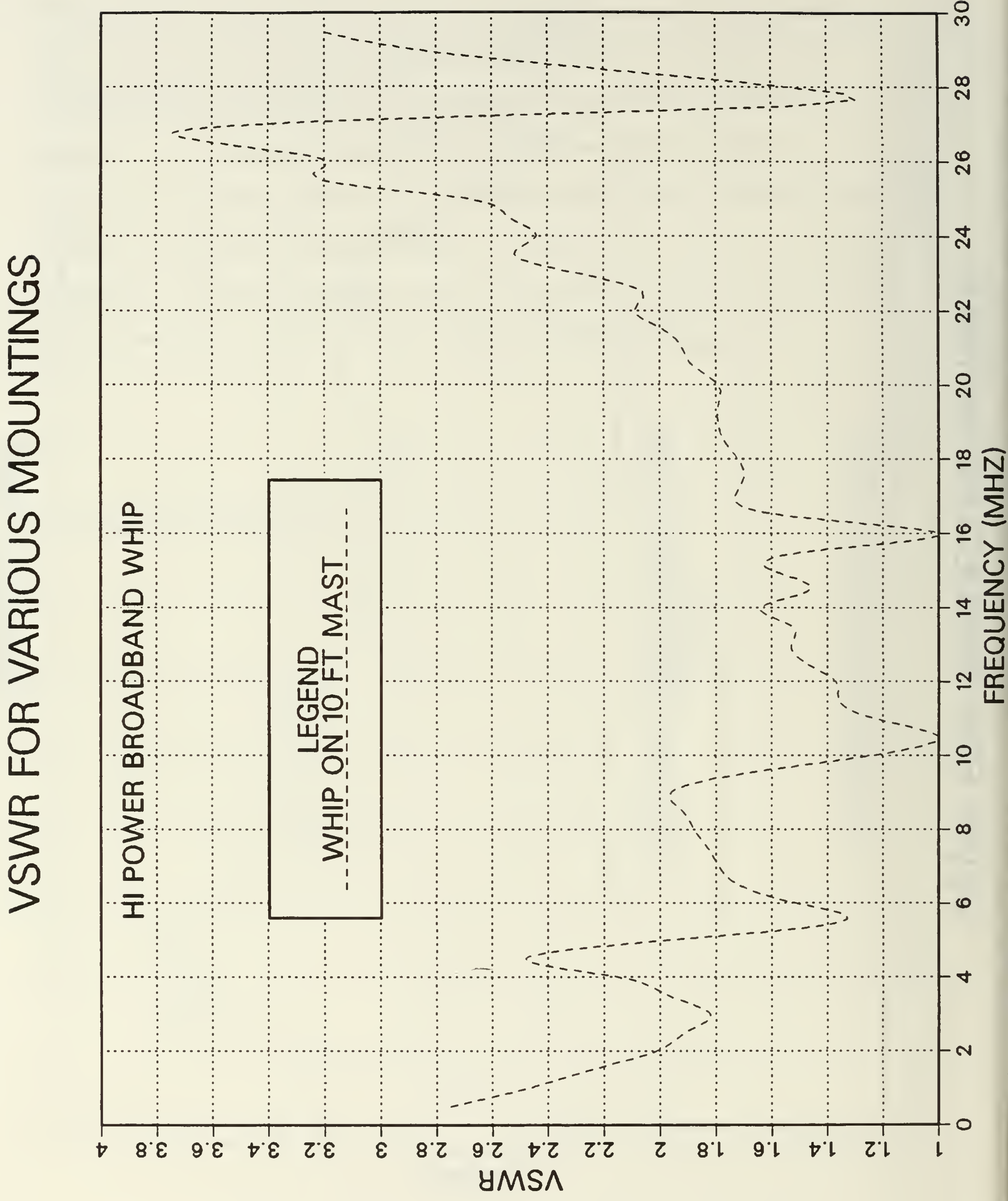

Fig. 2. VSWR vs. Frequency for 10 Foot Mast Mount

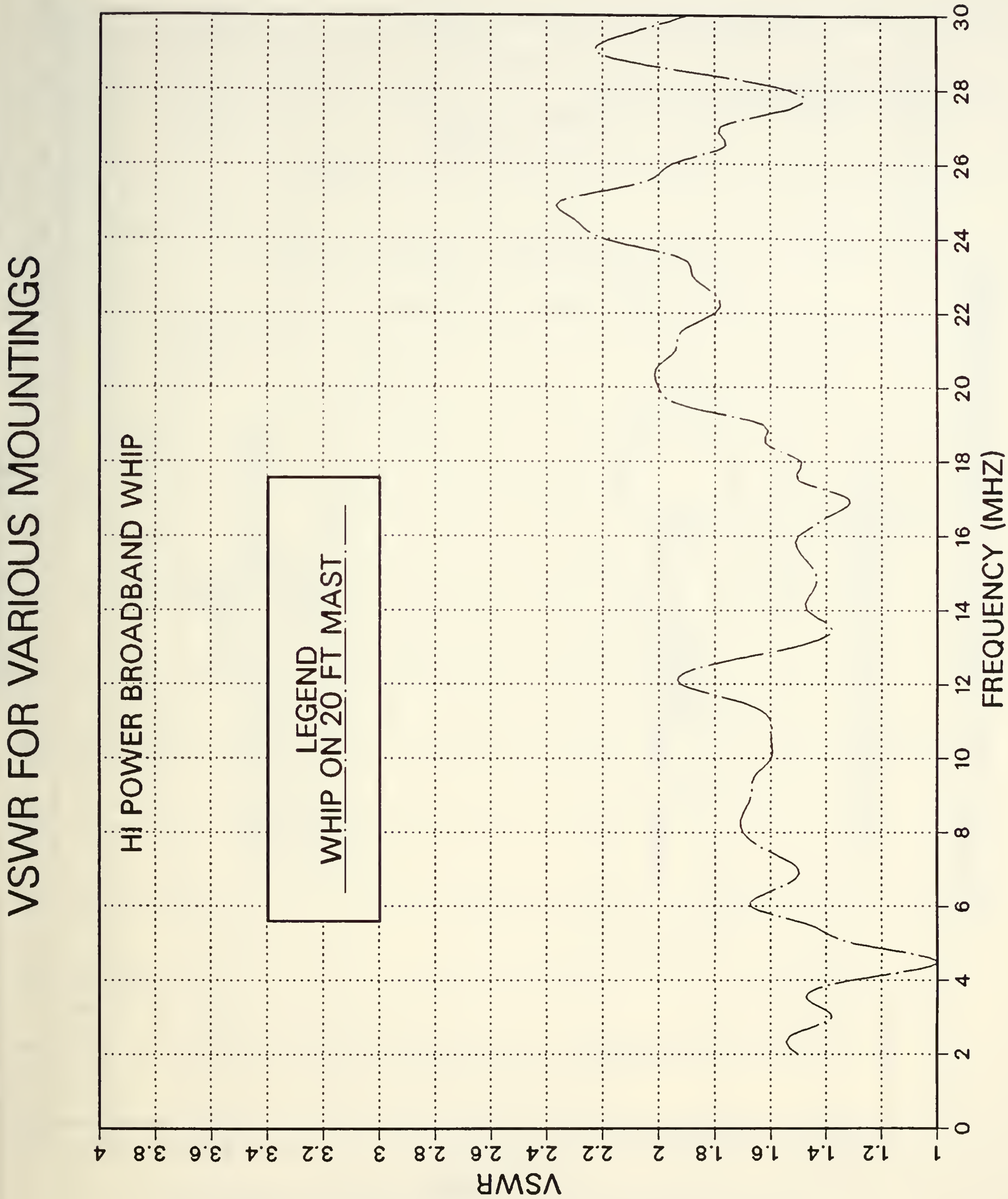

Fig. 3. VSWR vs. Frequency for 20 Foot Mast Mount

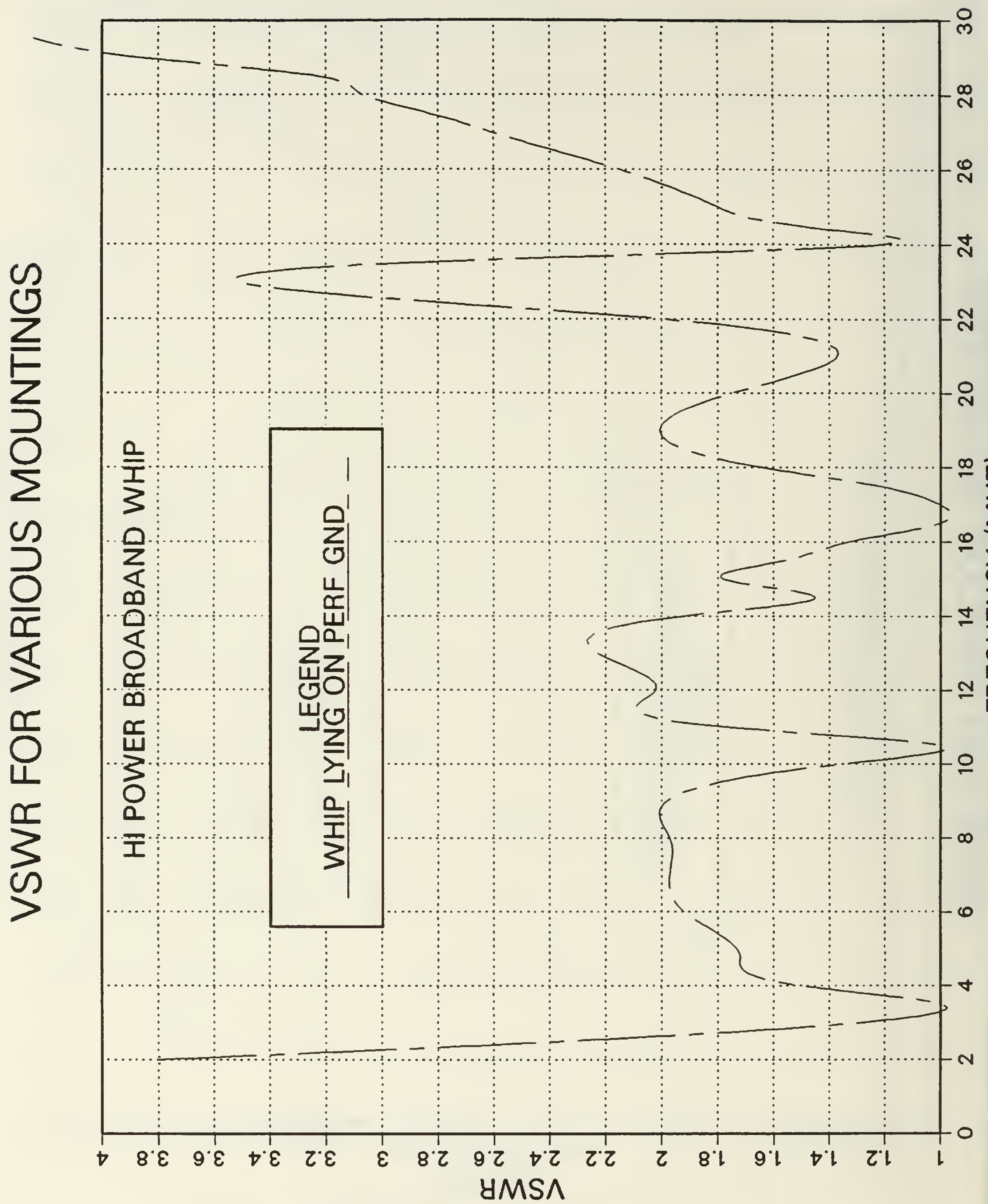

Fig. 4. VSWR vs. Frequency for Whiplying on Ground Plane

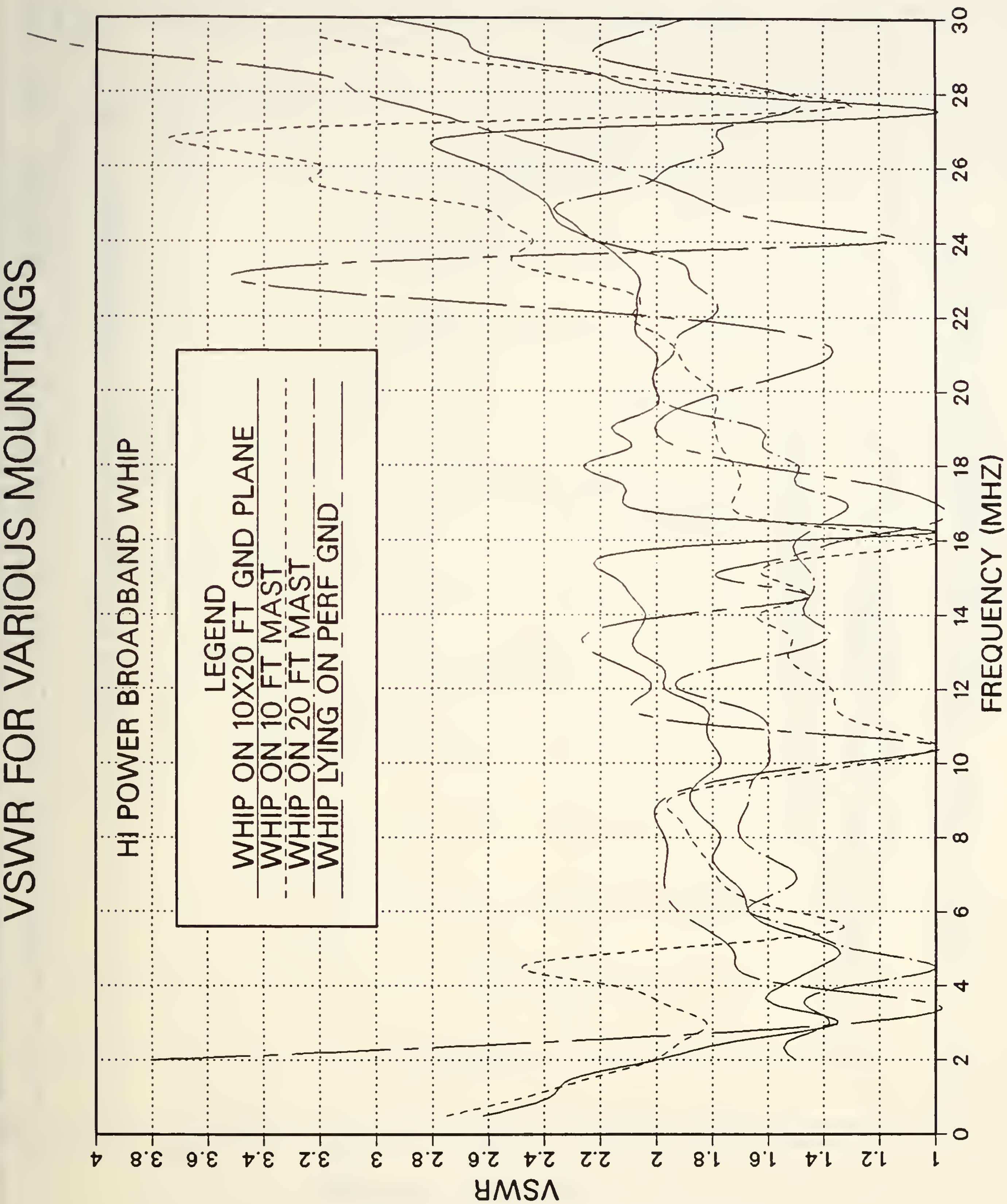

Fig. 5. VSWR vs. Frequency for Various Mountings

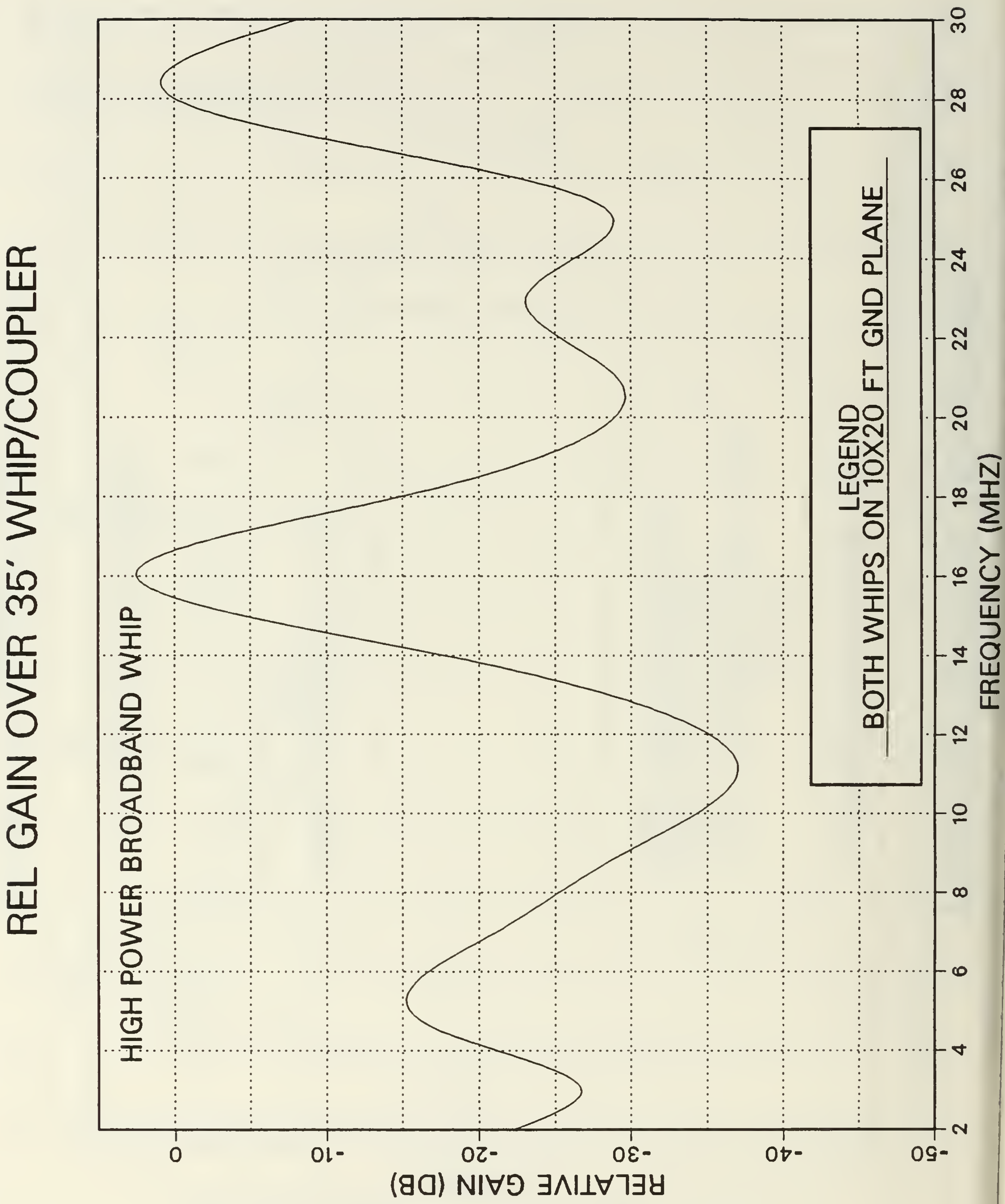

Fig. 6. Relative Gain Over 35 Foot Whip/Coupler

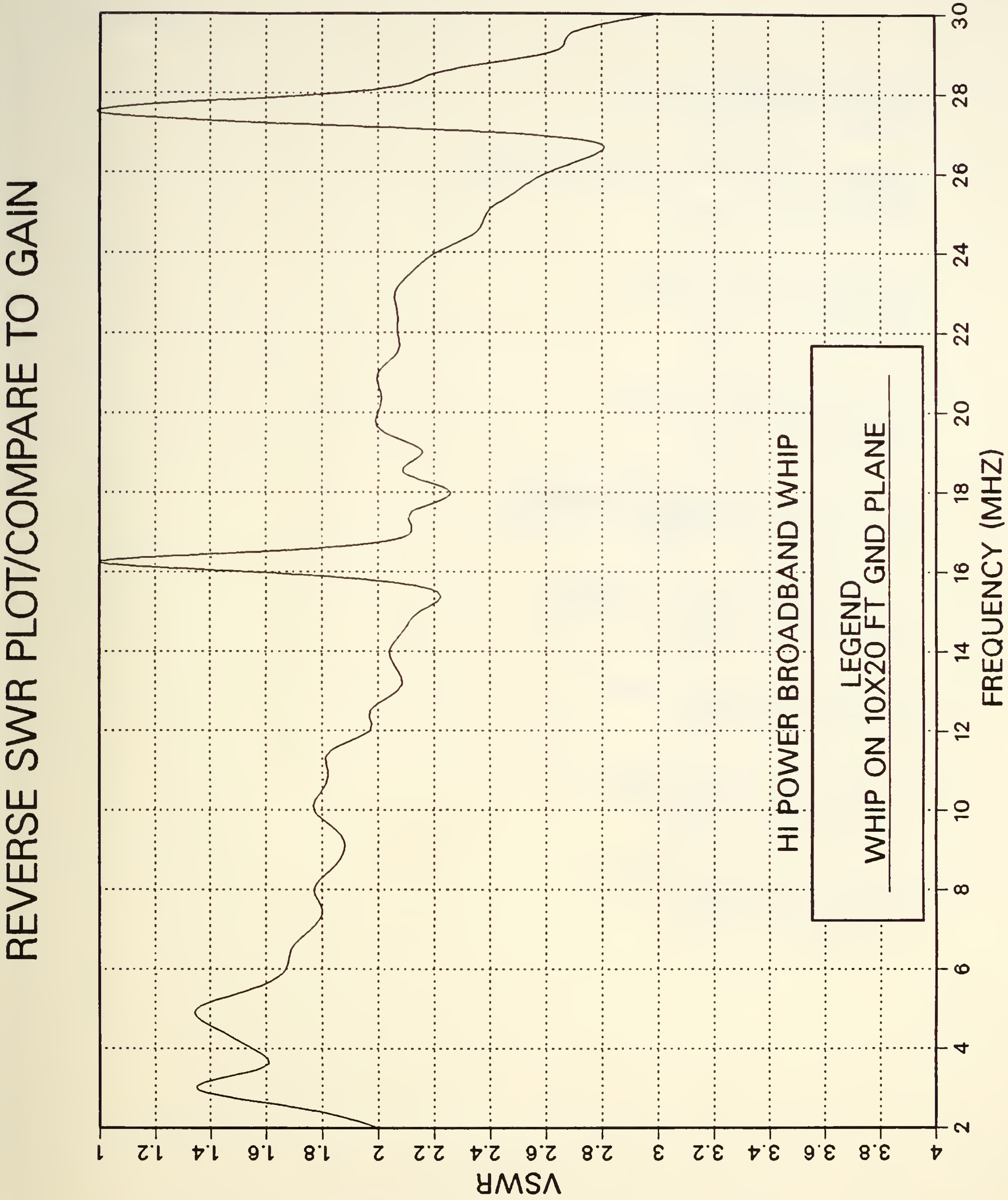

Fig. 7. Reverse VSWR for Comparison to Gain

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